Effectiveness of Cabs for Dust and Silica Control on Mobile Mining Equipment

Joseph J. Garcia,[1] Ronald E. Gresh,[1] Mary Beth Gareis,[2] and Robert A. Haney[2]
[1]Coal Mine Safety and Health, District 2 Hunker, PA,15639, U.S.A.;
[2]Mine Safety and Health Administration, Pittsburgh, PA, 15236, U.S.A.

ABSTRACT

The Mine Safety and Health Administration (MSHA) has conducted a study to evaluate the effectiveness of cabs for controlling silica dust exposure during operation of mobile mining equipment. This study focused on bulldozers, front-end loaders and haul trucks, was conducted at surface coal mining operations and underground metal and nonmetal mining operations. Each piece of equipment tested was equipped with a cab. The vehicles sampled were from a range of manufacturers having different types of filter media and air intake configurations. The purpose of this study was to determine the reduction of dust and silica exposure that could be achieved through the use of a well-maintained cab.

For each piece of equipment, dust and silica concentrations inside and outside the cab were determined and compared. In some cases, filtration efficiencies could be calculated. A properly designed environmental cab is sealed, has an intake air filtration system, and a heating and cooling system. Cabs should have good seals around the doors and windows. Factors such as cab pressurization filtration systems, filter media, and maintenance practices were also examined. In some cases, dust and silica reduction of 90 to 95% were observed.

KEYWORDS

Cab, Dust Control, Mobile Equipment, Quartz, Respirable Dust, and Environmental Cab.

INTRODUCTION

In many cases an environmental cab serves as the primary method of dust control for operators for both surface and underground mobile equipment. Environmental cabs, however, can only be effective when the equipment operators remain inside the cab. Historically, when the operator of a piece of mobile equipment has had a dust problem, an environmental cab could be installed to correct the situation. With more and more awareness of the problems associated with silica exposure on surface mining operations, a cab by itself can no longer be assumed to resolve the problems.

An environmental cab provides a controlled environment for the equipment operator. To obtain this controlled environment, the cab must be pressurized to keep outside dust from entering the cab through cracks in the windows and doors. The pressurizing air must be filtered to keep dust-laden air from entering the cab. Doors and windows must be sealed to limit the air needed for pressurization, and in most cases, an air conditioning/heating system is required to provide comfort for the operator.

As part of its surface dust initiative, the Mine Safety and Health Administration (MSHA), Coal Mine Safety and Health initiated a program to determine the dust control limitations of cabs versus environmental cabs. The purpose of this portion of the study was to determine the effectiveness of existing these cabs for dust and quartz control and to determine what types of improvements could be made to cab air-filtration systems through the use of improved filtration media and filtration and pressurization of the cab.

TYPES OF CONTROLS

Environmental cabs on new equipment are designed to meet ISO Standard 10623 (ISO, 1994). This standard provides for a 50 Pascal (0.20 inch of water) cab pressure and a minimum 0.12 m^3/s (25 cfm) of intake airflow into the cab. To achieve this design standard, cabs are tightly sealed and equipped with a fresh air intake system, a filtered recirculating system and an air conditioner. Figure 1 shows a front-end loader (highlift) and a bulldozer with a factory installed cab.

Cabs are sealed by placing rubber gaskets around the windows and doors. Tight latches and jambs are also placed on the windows and doors. Cab volumes are typically two to three cubic meters (70 to 105 cubic feet).

Intake air typically ranges from 0.012 to 0.036 m^3/s (25 to 75 cfm). This airflow is limited by the air-conditioning capacity. This provides approximately 0.5 to 1.25 air changes per minute inside the cab. A higher airflow would exceed the capacity of the air-conditioning system. While a lower airflow could make the operator feel uncomfortable and would result in the operator opening windows.

Many cabs have both intake and recirculating air systems. The intake air-filtration system typically consists of a pleated paper element. Some filtration systems have a prefilter in front of the pleated paper intake filter. The airflow for the intake and recirculating air systems can be provided by a single fan (blower) or by separate fans. The airflow for the recirculating system is typically 0.094 to 0.140 m^3/s (200 to 300 cfm). This airflow is cooled and filtered. The filtration system uses either a foam filter or a pleated paper filter. The air-conditioning capacity can be as high as 20,000 BTU.

When both intake and recirculating airflow are supplied by the same fan, changing a filter(s) media without adjusting the resistance on the system can result in a loss of cab air pressure. While many filtration materials are available, operators are generally limited to the filter cartridge supplied by the manufacturer, as each machine has a different size filter cartridge. Some aftermarket filter cartridges are available.

Many pieces of equipment either did not come with either an enclosed or environmental cab or the cab has deteriorated to the point where it is ineffective. In these situations, the equipment must be retrofitted with a cab and/or a filtered pressurizing and air-conditioning system. There are a limited number of suppliers of these products. However, the same principles apply to retrofitted cabs. The cab should be well sealed around doors and windows. The pressurizing unit should supply one air change per minute of filtered air and the cab should have a filtered heating/air-conditioning system for operator comfort.

METHODS OF EVALUATION

To evaluate the effectiveness of a cab, dust samplers were placed inside and outside of a cab. The samplers were operated for the entire shift and the respective respirable dust concentrations were calculated. The efficiency of the cab was determined by taking the difference between the outside and inside respirable dust concentration and dividing by the outside dust concentration. Cab pressure was measured with a Magnehelic water gage with the windows and doors closed.

Respirable dust concentrations were determined by the following equation. Mine Research Establishment (MRE) equivalent concentrations were calculated for coal mine dust samples by multiplying by the constant factor 1.38.

Concentration (time weighted average) =

$$\frac{\text{Mass (mg)} \times 1000\ (\text{L/m}^3) \times (1.38^*)}{\text{Flow rate LPM} \times \text{Time (min.)}}$$

*MRE Conversion Factor (respirable coal mine dust samples only)

Concentration reduction percentages from outside to inside the cab were based on the measured concentrations and were determined by the following formula:

$$\frac{[\text{Concent. Outside (mg/m}^3) - \text{Concent. Inside (mg/m}^3)] \times 100}{\text{Conc. Outside (mg/m}^3)}$$

Three types of cab air-filtrations systems were tested. These included:

1. standard factory installed systems,
2. improved filter media on a factory installed system, and
3. a retrofitted cab pressurizing system.

Retrofitting an existing cab with the original equipment manufacturer's air filtration system is not often feasible. The original equipment manufactured (OEM) has a detailed parts list for the air-filtration system. It is difficult for a local supplier to get all the parts necessary. There is a limited number of suppliers of retrofit cab pressurizing units and cab air-conditioning units.

In addition to the respirable dust samples, total dust samples were collected outside the cab for size distribution analysis. Particle-size distributions were obtained for the samples with sufficient weight gain using the Coulter Counter analytical techniques.

Tests were conducted at surface coal mines and underground nonmetal mines. Fourteen tests were conducted on 10 pieces of equipment.

RESULTS OF TESTS

Table 1 shows the results of the cab efficiency for dust and quartz, inside dust level and cab pressure for each of the factory installed systems evaluated. The systems tested had a wide range of performance. In most cases, factory installed cab air-filtration systems can reduce dust levels inside the cab to below 0.2 mg/m^3. The best factory installed system had a prefilter followed by a pleated paper inlet filter and a foam recirculating filter. The worst system had both an inlet air and recirculating filter but had not been maintained which rendered the system ineffective. The wire mesh filter also had a low performance.

Figure 2 shows seven vehicles from the study that had greater than 80% quartz reductions in the cab. The cabs all had pleated paper filters for one component of its filtration system. The cab that achieved the greatest quartz reduction was the unit that had a three-stage filtration system (fiber prefilter, pleated paper inlet filter, foam recirculating filter). This vehicle was the only three-stage filtration system that was tested.

In situations where the quartz content of the dust exceeds 50%, it may be necessary to replace standard cab filters with higher efficiency filters. Table 2 shows the results of tests conducted on two pieces of equipment where the standard cab filters were replaced with high efficiency filters. Tests on the improved efficiency filter, (with improved filter seals) indicated that up to a 98% reduction in silica could be achieved. In both cases the use of improved filtration media reduced the dust and silica exposure. In one case, however, it resulted in a reduction of cab pressure because the system airflow was not balanced with the new filter. When improved filtration is needed, the mine operator needs to make sure that the higher efficiency filters do not restrict or unbalance the cab airflow which can result in a loss of cab pressurization.

A cab should be pressurized at a 50 Pa (0.2 inch of water) minimum, have a filtered intake air supply and a filtered recirculating air-conditioning system. Increased positive pressure will reduce the dust concentration inside the cab keeping unfiltered air out of the cab. Some cabs were effective with pressures below the design level of 50 Pa, however when the cab pressure was below 10 Pa (0.04 inch of water), the cab was ineffective. When the window was opened, the differential pressure dropped off to zero, indicating that in order to maintain a positive pressure within the cab, a good seal around windows and doors on the cab is critical. Additionally, a good seal around the filter cartridge is essential to avoid intake air contamination.

A manufacturer's filter replacement recommendation is often based on operation time or applications other than mining. A clogged filter can render a cab ineffective for dust control. Filters should be replaced either at the manufacturer's recommendation, weekly, or when the cab air pressure drops below one-half of the clean filter value. A pressure indicator should be installed to indicate when filters should be replaced.

Table 3 shows the results of the cab efficiency for dust and quartz, inside dust level and cab pressure for each of the field retrofitted system evaluated. A cab without additional controls provides some additional protection to the worker. Probably because it protects the worker from peak concentrations.

The commercially available pressurizing unit reduced dust and silica levels insides the cab by approximately 90%. However, it did not provide the 50 Pa of pressurization even though it provided approximately one air change per minute. Additional cab sealing and/or airflow would be needed to provide the desired pressurization.

Good housekeeping and hygiene practices should be followed to avoid contamination of the cab. Housekeeping practices should include vacuuming or wet wiping the cab interior daily, replacing filters as necessary, periodically cleaning the inside of air ductwork and making sure doors and windows are sealed. In addition, the equipment operator should wear clean clothes and boots to reduce contamination of the cab.

Results of size distribution analysis indicate that the total dust outside the cabs had a mass median diameter ranging from approximately seven to nine micrometers. This is important in the selection of filter material and cab fan capacities. Current cab filtration systems are often designed for agricultural dust which typically has a mass median diameter greater than 10 micrometers.

CONCLUSIONS AND RECOMMENDATIONS

1. In most cases, factory installed environmental cab air-filtration systems can reduce dust levels inside the cab to below 0.2 mg/m^3.

2. In situations where the quartz content of the dust exceeds 50%, it may be necessary to replace standard cab filters with higher efficiency filters. When this is needed, the operator must make sure that the higher efficiency filters do not restrict or unbalance the cab airflow which can result in a loss of cab pressurization.

3. Field tests on an improved efficiency filter, (with improved filter seals) indicated that in some cases, a 98% reduction in silica could be achieved.

4. To be effective, a cab should be pressurized at a minimum of 50 Pa (0.2 inch of water), have a filtered intake air supply and a filtered recirculating air- conditioning system.

5. Because of heavy dust loading, filters may need to be replaced more frequently than the manufacturer's recommendation. Cab filters should be replaced when the cab air pressure drops below one-half of the clean filter value. (A clogged filter can render a cab ineffective for dust control.)

6. A pressure indicator should be installed to indicate when filters should be replaced.

7. A cab that does not provide environmental control, may provide some protection to the worker inside the cab by reducing exposure to peak dust concentrations.

8. A commercially available pressurizing unit, that filtered the pressurized air reduced dust levels inside the cab up to 90%.

9. Housekeeping practices should include vacuuming or wet wiping the cab interior daily, replacing filters as necessary, periodically cleaning the inside of air ductwork and making sure doors and windows are sealed. In addition, the equipment operator should wear clean clothes and boots to avoid contamination of the cab.

10. Based on the interest demonstrated during this project, one equipment manufacturers is developing a retrofit cab for equipment that was not originally supplies with a cab or the cab has deteriorated.

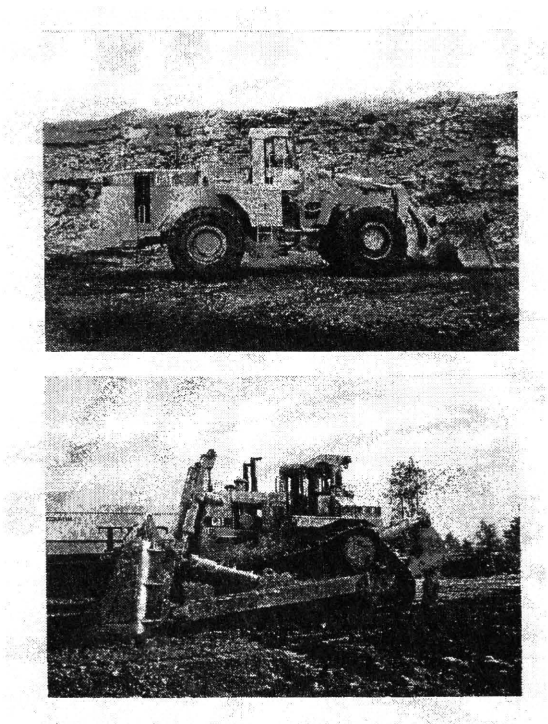

Figure 1. Photos of front-end-loader (above) and bulldoze (below) with factory equipped cabs.

REFERENCES

ISO 10623:1994, Earth Moving Machinery - Operator Enclo sure Environment.

Office of the Federal Register, 1998, Code of Federal Regula tions, Mineral Resources, Title 30, U.S. Government Printing Office, Washington.

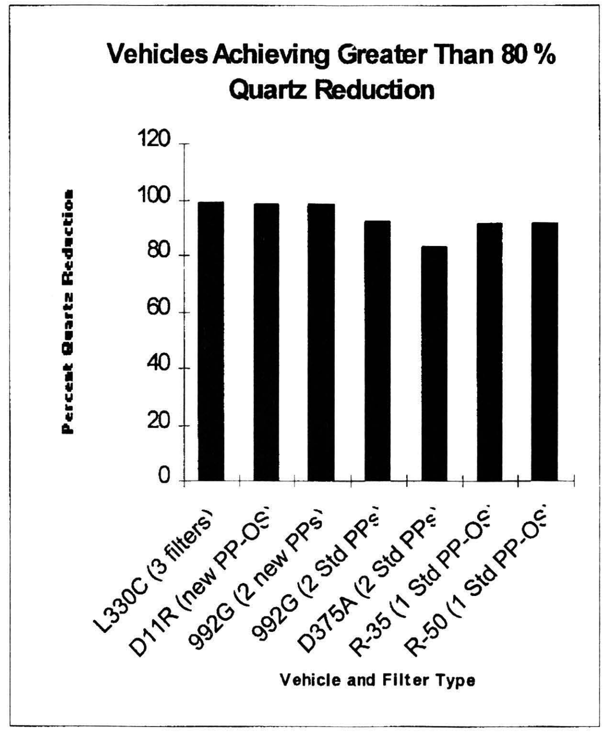

Figure 2. Vehicles having greater than 80 percent Quartz reduction.

Table 1. Evaluation of factory installed cab filtration systems.

Manufacturer	Type of Equipment	Type of Filters	Percent Dust Reduction	Percent Quartz Reduction	Dust Level Inside Cab mg/m³	Quartz Level Inside Cab µg/m³	Cab Pressure inches water
Caterpillar (Sur. Coal)	D11R Dozer	Std. PP-OS Std. PP-IS	68	71	0.21	118	0.16 - 0.30
Caterpillar (Sur. Coal)	992G Loader	Std. PP-OS Std. PP-IS	86	92	0.06	14	0.24 - 0.62
Komatzo (Sur. Coal)	D375A Dozer	Std. PP-OS Std. PP-IS	54	83	0.10	13	0.02 - 0.14
Komatzo (Sur. Coal)	W600 Loader	Std. PP-OS Std. FM-IS	0	49	0.30	14	0.00 - 0.04
Volvo (UG Metal)	L330C Loader	Std. FB-PF Std. PP-OS Std. FM-IS	94	99	0.10	7	0.28
Euclid (UG Metal)	R-65 Truck	MM-OS FM-IS	68	50	0.36	6	--
Caterpillar (UG Metal)	992C Loader	Std. PP-OS Std. PP-IS	80	70	0.45	7	--
Caterpillar (Sur. Metal)	980F Loader	Std. PP-OS	72	78	0.05	5	0.04
Euclid (UG Metal)	R-35 Truck	MM-OS	13	0	0.93	81	0.00
Euclid (UG Metal)	R-50 Truck	MM-OS	40	42	0.80	61	0.00

Table 2. Evaluation of high efficiency cab filtration systems.

Manufacturer	Type of Equipment	Type of Filters	Percent Dust Reduction	Percent Quartz Reduction	Dust Level Inside Cab mg/m³	Quartz Level Inside Cab µg/m³	Cab Pressure inches water
Caterpillar (Sur. Coal)	D11R Dozer	Std. PP-OS Std. PP-IS	68	71	0.21	118	0.16 - 0.30
Caterpillar (Sur. Coal)	D11R Dozer	New PP-OS Std. PP-IS	45	78	0.08	17	0.06 - 0.21
Caterpillar (Sur. Coal)	992G Loader	Std. PP-OS Std. PP-IS	86	92	0.06	14	0.24 - 0.62
Caterpillar (Sur. Coal)	992G Loader	New PP-OS New PP-IS	93	98	0.02	4	0.29 - 0.69

Table 3. Evaluation of retrofit cab pressurization systems.

Manufacturer	Type of Equipment	Type of Filters	Percent Dust Reduction	Percent Quartz Reduction	Dust Level Inside Cab mg/m^3	Quartz Level Inside Cab $\mu g/m^3$	Cab Pressure inches water
Euclid (UG Metal)	R-35 Truck	MM-OS	13	0	0.93	81	0.00
Euclid (UG Metal)	R-35 Truck	Std. PP-OS	91	91	0.10	8	0.04
Euclid (UG Metal)	R-50 Truck	MM-OS	40	42	0.80	61	0.00
Euclid (UG Metal)	R-50 Truck	Std. PP-OS	92	91	0.07	5	0.04

PP - Pleated Paper
FB - Fiber
FM - Foam
MM - Metal Mesh
OS - Outside
IS - Inside

Note: The reference to a specific manufacturer does not constitute and endorsement of that equipment.